ANSI/AIAA S-120A-2015(2019)

Standard

Mass Properties Control for Space Systems

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American National Standard

Mass Properties Control for Space Systems

Sponsored by

American Institute of Aeronautics and Astronautics

and International Society of Allied Weight Engineers, Inc.

Approved 14 October 2015

American National Standards Institute

Approved 23 November 2015

Abstract

Mass properties control is a critical aspect of space system development. This standard and International Society of Allied Weight Engineers, Inc., RP A-3, Recommended Practice for Mass Properties Control for Space Systems, together define terminology and establish uniform processes, procedures, and systematic methods for the management, control, monitoring, determination, verification, and documentation of mass properties during the design and development phases of space systems, including modifications to operational systems. This standard and the recommended practice apply to space vehicles, upper stage vehicles, injection stages, payloads, reentry vehicles, launch vehicles, and ballistic vehicles. This standard is intended to convey minimum requirements applicable to space system development, while the recommended practice is intended to be used as a reference for the development of a program-specific, contractually required mass properties control plan.

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Foreword

This revision of the Mass Properties Control for Space Systems Standard was developed in response to contractors who noted that there were implicit requirements called out in AIAA S-120-2006 (denoted by the use of the word “shall”) that were not true requirements, thus adding unnecessary costs to contracts. In response, a Mass Properties Engineering (MPE) Committee on Standards (CoS) was formed and voted unanimously to revise the existing standard.

The International Society of Allied Weight Engineers, Inc. (SAWE), a major source of MPE Subject Matter Experts, signed a Memorandum of Understanding to jointly develop both a revised standard and a revised recommended practice with the American Institute of Aeronautics and Astronautics (AIAA) CoS.

The new revisions, designated as AIAA S-120A-2015 and SAWE RP A-3, are intended to fully replace AIAA S-120-2006 and SAWE RP-11C. When a requirement is identified in a subsection of section 5 of this standard, the corresponding recommended practice is described in the same numbered subsection of RP A-3.

This standard is intended to convey the minimally acceptable mass properties requirements for space systems, while the associated SAWE RP A-3, Mass Properties Control for Space Systems, provides guidance for implementation of a program-specific mass properties control plan. Together, the two documents may also be used to establish requirements during preparation of acquisition contracts and program-specific documents.

This standard contains proven methods and lessons learned for effective mass properties control, combines tools necessary for timely evaluation of program mass properties, and enables early decision making regarding possible design changes.

The primary objective of this standard is to provide an effective means for meeting program requirements for space system mass properties control, analysis, verification, data management, and documentation. It is intended to be comprehensive and practical and will be periodically updated to incorporate advances and innovations.

At the time of approval, the members of the AIAA **Mass Properties Engineering Committee on Standards** were:

Geoffrey Beech, Chair	National Aeronautics and Space Administration (NASA) Marshall Space Flight Center
Mark Andraschko	NASA Langley Research Center (LaRC)
Jeffrey Bautista	Northrop Grumman
Jeffrey Cerro	NASA LaRC
William Griffiths	The Aerospace Corporation
Jennifer Herron	Action Engineering
Roland Holzmann	The Boeing Company
Robert Hundl	Fluor
Bell Lee	Raytheon
Daniel Kwon	Orbital ATK
Roland Martinez	NASA Johnson Space Center (JSC)
John Nakai	The Aerospace Corporation

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Clinton Plaisted	A.I. Solutions
Glen Richbourg	Lockheed Martin Space Systems Company
Ricardo Roy	United Launch Alliance
Robert Shishko	Jet Propulsion Laboratory
Paul Weitekamp	SpaceX
David Wolfe	Blue Origin
Robert Zimmerman	Retired

The above consensus body approved this document in June 2015.

The current members of the AIAA CoS wish to thank the following for their contributions to the initial release of this document: Tom Ajluni, Kevin Bee, Geoffrey Beech, Roger Belt, Gerard Drewek, David Finkleman, Michael Froehlich, William Griffiths, Mahantesh Hiremath, Gary Holloway, Roland Holzmann, Quang Lam, Bell Lee, Dean Liensdorf, Ian MacNeil, Thomas McGovern, John Nakai, Geoffrey Reber, Glen Richbourg, Ricardo Roy, Ronald Solomon, Richard Sugiyama, Joseph Vecera, Ernest Wade, Louis Yang, and Robert Zimmerman.

The AIAA Standards Executive Council (Mr. Allen Arrington, Chairman) accepted the document for publication in October 2015.

The AIAA Standards Procedures dictate that all approved Standards, Recommended Practices, and Guides are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. There is no agreement to adhere to any AIAA standards publication and no commitment to conform to or be guided by standards reports. In formulating, revising, and approving standards publications, the committees on standards will not consider patents that may apply to the subject matter. Prospective users of the publications are responsible for protecting themselves against liability for infringement of patents or copyright or both.

Annexes A, B, and C in this document are informative.

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1 Scope

This standard defines terminology and establishes uniform processes, procedures, and methods for the management, control, monitoring, determination, verification, and documentation of mass properties during the design and development phases of space systems, including modifications to operational systems. This standard applies to space vehicles (SVs) or spacecraft (SC), upper stage vehicles, injection stages, satellite payloads, reentry vehicles, launch vehicles (LVs), and ballistic vehicles. This standard defines a minimum set of mass properties requirements and is intended for use in developing a program-specific, contractually required mass properties control plan (MPCP). When used in conjunction with the International Society of Allied Weight Engineers, Inc. (SAWE) Recommended Practice RP A-3, the two documents serve as a comprehensive reference for requirements and best practices in the field of space systems mass properties.

2 Tailoring

When viewed from the perspective of a specific program or project context, the requirements defined in this standard may be tailored in a program-specific MPCP. The requirements of this standard are presented as a minimum set, and any changes or removal should be undertaken in consultation with the procuring authority and subject matter experts where applicable. For the purpose of this document, the 'customer' is the organization that sets the allowable mass, and the 'contractor' is the organization responsible for developing the system or sub-system within the allowable mass. For the purposes of this document the term program is used to refer to either a project or program.

NOTE Tailoring is a process by which individual requirements or specifications, standards, and related documents are evaluated and made applicable to a specific program or project by selection and, in some exceptional cases, modification and addition of requirements in the standards.

3 Applicable Documents

The following documents contain provisions which, through reference in this text, constitute provisions of this standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. For undated references, the latest edition of the document referred to applies.

SAWE RP A-3	*Mass Properties Control for Space Systems*
SAWE RP 6	*Standard Coordinate Systems for Reporting the Mass Properties of Flight Vehicles*
SAWE RP 16	*Measurement of Missile and Spacecraft Mass Properties*

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4 Vocabulary

4.1 Acronyms and Abbreviated Terms

3D	Three dimensional
ACS	Attitude Control System
AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
ATP	Authorization to Proceed
CAD	Computer-Aided Design
CCB	Change Control Board
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CFE	Customer-Furnished Equipment
CM	Center of Mass
CoS	Committee on Standards
ECLSS	Environmental Control and Life Support System
EIDP	End Item Data Package
FBS	Functional Breakdown Structure
GSE	Ground Support Equipment
H	High (probability of occurrence)
ID	Identify
IPT	Integrated Product Team
ISO	International Organization for Standardization
JSC	Johnson Space Center
kg	Kilogram
L	Low (probability of occurrence)
LaRC	Langley Research Center
LV	Launch Vehicle
M	Medium (probability of occurrence)
MGA	Mass Growth Allowance
MIL-HDBK	Military Handbook
MOI	Moment(s) of Inertia
MP	Mass Properties

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MPCB	Mass Properties Control Board
MPCP	Mass Properties Control Plan
MPE	Mass Properties Engineer, Mass Properties Engineering
NASA	National Aeronautics and Space Administration
NTE	Not to Exceed
PDR	Preliminary Design Review
POI	Product(s) of Inertia
PSRR	Pre-shipment Readiness Review
RP	Recommended Practice
SAWE	International Society of Allied Weight Engineers, Inc.
SC	Spacecraft
SV	Space Vehicle
SWI	Standard Work Instruction
TP	Test Procedure
TPM	Technical Performance Measurement
VDL	Variance Discrepancy Log
WBS	Work Breakdown Structure

4.2 Terms and Definitions

For the purposes of this document, the following terms and definitions apply. Annex A provides vehicle-specific graphical summaries of the relationships between key definitions.

Actual Mass Properties
mass properties determined by measurement or by comparison of nearly identical components, for which measured mass properties are available (assessed as maturity category A5 or A6 in Table 1)

Allowable Mass
the limit against which mass margins are calculated

NOTE 1 The allowable mass is a derived requirement set early in the program and is intended to remain constant until there is a change in requirements.

NOTE 2 Examples of an allowable mass include a contractor not-to-exceed (NTE) mass limit or an informal mass allocation to a design organization.

Balance Mass
mass added to a system or component to achieve static or dynamic balance

Ballast
mass that may be added, removed, or relocated to meet mass properties, stability, or orbital injection requirements

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Baseline
the current state of requirements, design definition, and other formally controlled Program documentation

Basic Mass
the current mass of dry hardware based on an assessment of the most recent baseline design

NOTE 1 The design assessment includes the estimated, calculated, or measured (or actual) mass and includes an estimate for undefined design details like cables, multi-layer insulation, and adhesives.

NOTE 2 The mass growth allowances (MGA) and uncertainties are not included in the basic mass.

NOTE 3 Basic mass is sometimes referred to as Current Best Estimate.

Bulk Item
a constituent of an assembly or part that is not readily identified by an exact quantity or graphical representation and where its shape, volume, and mass may be determined upon installation or by a note only. These items generally have a quantity of "as required" in the parts list, e.g., paints, structural adhesives, fluids, tapes.

Bus
the portion of an SV that supports payloads and performs functions related to the SV's basic operation and maintenance, such as flight control, power, and propulsion

Calculated Mass Properties
mass properties determined from preliminary or released drawings or controlled computer models (assessed as maturity category C3 or C4 in Table 1)

Center of Mass (CM)
the point at which the distributed mass of a simple or composite body can be acted upon by a linear force without inducing any rotation of the body

Critical Mass Properties
those mass properties that have limits that would jeopardize mission performance or safety if exceeded

Dry Mass
the mass of a space system without propellants or inert fluids or gasses (e.g., pressurization gasses, hydraulic fluids)

Estimated Mass Properties
mass properties determined from preliminary data, such as sketches, analysis from preliminary layouts or models, or parametric data (assessed as maturity category E1 or E2 in Table 1)

Forecast Mass
predicted mass plus consideration for pending and potential mass changes

In-Scope Changes
design modifications implemented by the contractor to meet contractual requirements

Inert Mass
solids, liquids, and gasses onboard a space system that either are not expended during flight, or that are expended during flight but do not generate propulsive impulse for the space system

NOTE 1 Examples of inert fluids include hydraulic fluid, residual and unburnable propellant, and tank pressurization gas

NOTE 2 Examples of inert materials include ice, ablative heat shielding, solid rocket motor insulation, and nozzle liners

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Launch Vehicle
a space system whose purpose is to carry one or more payloads from the surface of Earth (or other celestial body) and deliver the payload(s) into space with position and velocity meeting desired target state vectors at the desired time

Mass
the measure of the quantity of matter in a body that results in the body's resistance to change in translational velocity

Mass Growth Allowance
the predicted change to the basic mass of an item based on an assessment of the hardware category, design maturity, and fabrication status

NOTE 1 MGA should be defined as part of contract negotiations.

NOTE 2 The alternate word "contingency" is vague and is no longer used to define MGA or margin.

Mass Limit
maximum mass that can satisfy all mission performance requirements

NOTE Also referred to as mission limit.

Mass Margin
mass available for in-scope changes calculated as the difference between the space system allowable mass and the predicted mass

Mass Properties
mass, CM, moments of inertia (MOI), and products of inertia (POI)

Mass Properties Control Board (MPCB)
a body tasked with reviewing and managing a space system's mass properties, typically to produce a minimum mass design consistent with mission requirements and to identify risks to the overall program resulting from any non-compliance with mass properties requirements

Mass Properties Database
a data management system used to record and manage the mass properties data records of a space system and its constituent parts

Mass Reserve
mass allowance defined and retained by the customer or program management for potential out-of-scope changes or any other unforeseen mass impacts

Moment of Inertia
a body's resistance to change in angular velocity about a defined axis resulting from the body's distribution of mass

Out-of-Scope Changes
design modifications that are not consistent with the current contract requirements

Overages
non-flight items on a test article when a measurement is conducted

Payload
for SVs, the on-board equipment that directly relates to the purpose of the system's flight; for LVs, the SV or delivered space system, payload-unique adapter, and other mission-peculiar flight hardware needed to support the functioning of the space system on the ground and during launch

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